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Mechanical properties of HIPS/sugarcane bagasse fiber composites after accelerated weathering

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Abstract

The effect of accelerated weathering on the visual appearance and on mechanical properties of high impact polystyrene (HIPS) as well as HIPS reinforced with mercerized and bleached sugarcane bagasse fibers composites are investigated. After accelerated weathering period of 900 h, under UV-B radiation and moisture regular cycles, changes in mechanical properties are investigated by tensile tests. Materials fracture surfaces are investigated by scanning electron microscopy (SEM). The study showed that the exposure time was sufficient to change the visual appearance of HIPS as the composites. From this study, it was observed that composites reinforced with bleached fibers are less susceptible to accelerated weathering exposure than composites reinforced with mercerized fibers, which is explained by the higher amount of lignin present in mercerized fibers.

Keywords: sugarcane bagasse fibers; high impact polystyrene; UB-b radiation; degradation;mechanical properties

1. Introduction

The study of polymeric composites exposed to ultra-violet (UV) and moisture with consequent degradation has attracted the attention of many researchers. The ultra-violet radiation absorbed by polymers produces different effects when degradation process is considered, since this phenomenon modifies the chemical structure, providing molecular chain scission and/or chain crosslinking [1, 2, 3, 4].

Degradation processes such as photo-radiation, thermal degradation, photo-oxidation and hydrolysis are able to provide changes in the chemical, physical and mechanical properties of materials [5].

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In polymeric matrix, degradation by weathering, as UV radiation and moisture exposition, can be occur through some mechanism of photo-oxidation such as: free radicals formation, chain scissions, occurrence of fragility and changes of color [2, 6].

According to Parres et al. [2] styrene polymers are highly sensitive to photo-degradation, and within this group high impact polystyrene is particularly susceptible to this type of degradation, due to the presence of butadiene in its structure, since double bonds are particularly sensitive to the action of UV radiation.

In polymeric composites reinforced with synthetic fibers and/or natural fibers, the exposure to accelerated weathering not only affects the polymeric matrix itself, but also acts upon other components within the matrix, such as pigments, processing additives and reinforcements [5,7].

For the lignocellulosic fibers, the mechanisms of aging or degradation may occur due to: ultra-violet radiation absorption by lignin, formation of quinoid structures, Norrish reactions and reactions of photo-yellowing occur in lignin [6, 7].

Degradation study by exposure to weathering, combined action of UV radiation, heat and moisture, can be accomplished through natural or artificial aging.

Natural aging process consists of a material subjected to the influence of natural elements, weathering or the action of the environment in which the material is subjected to conditions of use [7, 8].

Accelerated aging process occurs in aging chambers that simulate a natural environment in a controlled manner. The advantage of using the analysis of degradation in a chamber made of artificial weathering is that, besides being faster than natural exposure, there is an important feature to be reproducible [7]. Moreover results have no exact correlation to what happens in reality due to the regularity of cycles - duration, intensity and exposure conditions.

The effects of degradation due to natural or artificial aging can be evaluated through the quantification of chemical degradation and/or by analysis of physical properties such as mechanical behavior and visual appearance [7].

In this context, the objective of this work is to evaluate the effect of accelerated weathering on the mechanical properties of polymer composites with a high impact polystyrene (HIPS) as a matrix, reinforced with mercerized and bleached sugarcane bagasse fiber. Tensile specimens of composites with different fiber volume were exposed to alternating cycles of UV-B radiation and moisture during 900 hours in a chamber of UV/condensation. After 900 hours of exposure, the specimens were mechanically tested by tensile tests in order to verify the influence of degradation process on the mechanical properties of materials.

2. Experimental

2.1. Materials

Sugarcane bagasse fibers were supplied by Edras Ecossistemas. Fibers were dried at 50°C for an hour, and after being ground in a mill, finally sieved to obtain a sample that passed through a 45 mesh (opening 354 μm). The HIPS 825 used in this study was produced by FINA Tecnology, Inc and supplied by Videolar.

2.2. Sugarcane bagasse fiber treatments

Sugarcane bagasse fibers (100g) were pre-treated with 1 L alkaline solution containing 10 g sodium hydroxide (1% w/w), for an hour under constant stirring at room temperature. Once the time of treatment was reached, the solution was filtered in a vacuum filter and fibers were washed with distilled water until

neutral pH was attained. Then, fibers were dried in an oven at 50°C for 24 hours.

The mercerized fibers (24 g) were bleached with 200 mL solution containing 1 mL acetic acid and 3 g sodium chloride (80%).This solution was stirring for 2 hours at 70°C, followed by filtration under vacuum and washing with distilled water until neutral pH. Finally, bleached fibers were dried in an oven at 50 ºC for 24 hours.

2.3. Composites preparation

The mercerized and bleached sugarcane bagasse fibers were mixed with the polymeric matrix (HIPS) in a thermokinetic mixer model MH-50H, with the speed rate kept at 5250 rpm, in which fibers were responsible for 10 and 20 wt% of the composition as presented in Tab 1.

Table 1. Compositions of investigated systems

Material	Fiber treatment	Loading (%)
HIPS/10MBF	mercerized	10
HIPS/20MBF	mercerized	20
HIPS/10BBF	bleached	10
HIPS/20BBF	bleached	20

After mixing, composites were dried and grounded in a mill model RONE. Then, fibers/HIPS composites were placed in an injector chamber at 200°C and heated at a 2ºC/min rate. The melted material was injected in required dimensions, in a pre-warm mold (210°C) in order to obtain tensile specimens.

2.4. Accelerated weathering exposure

Accelerated weathering testing was carried out using an accelerated weathering tester (Model QUV-Accelerated Weathering Testers) following the ASTM G-154, using a fluorescent bulb UVB-313 with 0.76W (m^2.nm) irradiance, with repetitive cycles of UV irradiation for 8 h at 60°C followed by 4 h water condensation at 50°C.The samples were submitted to the aging process for 900h.

2.5. Tensile tests

Five specimens of composites and of pure HIPS, before and after the exposure period, were analyzed in a Shimatzu testing machine (model AG-X 50 kN). Tests were carried out according to ASTM D638 standards with a load cell of 50 kN and at a speed of 5 mm/min.

2.6. Scanning electron microscopy

Fracture surface of composites were analyzed with a LEO 1450V scanning electron microscope with a tungsten filament operating at 20 kV, using a low vacuum technique and a working distance of 12 mm.

3. Discussions and Results

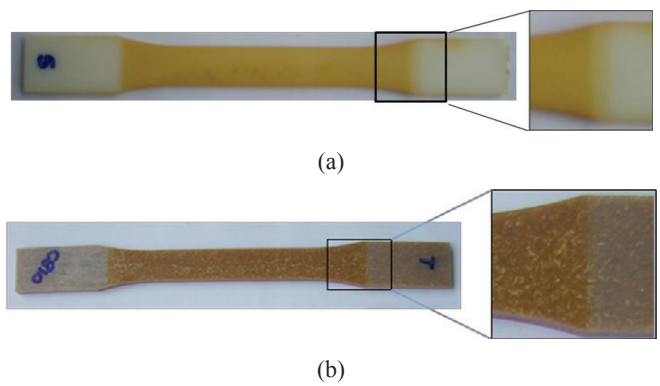
Some of major changes that a material degraded by UV radiation may suffer are yellowing, changes in

surface appearance of the material and reduction of mechanical and other general properties [6,8].

In the case of the material analyzed in this study, exposure to weathering caused yellowing, but no changes in the ultimate tensile of HIPS was observed, probably due to the short period of exposure, on the other hand the exposure provided a small increase in tensile modulus.

This increase in the matrix tensile modulus, also observed by Borrelly [7], might have been caused by the onset of a crosslinking process that occurs with some thermoplastics subjected to certain processes of degradation [9].

The color change or yellowing observed in images of Fig 1 was mainly due to the formation of quinines from aromatic vinyl benzene present in polystyrene and due to photooxidation of lignin under ultraviolet radiation [10].



(a)

(b)

Fig. 1. Specimens of HIPS and composite after accelerated weathering exposure period: (a) HIPS; (b) HIPS/10BBF

Results of the tensile strength and tensile modulus of the materials before and after weathering are presented in Tab 2. The addition of fibers as reinforcement provided a decreasing of ultimate tensile strength according to the fiber volume increased.

Table 2. Mechanical properties of composites before and after the exposure of accelerated weathering

Composites	Ultimate Tensile (MPa)	Ultimate Tensile (MPa) - AW*	Tensile Modulus (MPa)	Tensile Modulus (MPa)- AW*
HIPS	24.6 ±0.1	24.6 ±0.5	3.0 ±0.1	3.4 ±0.1
HIPS/10MBF	25.1 ±0.2	23.8 ±0.3	3.5 ±0.1	3.8 ±0.1
HIPS/20MBF	27.7 ±0.4	22.8 ±0.7	4.8 ±0.2	4.8 ±0.3
HIPS/10BBF	24.1 ±0.1	24.2 ±0.8	3.4 ±0.1	3.6 ±0.6
HIPS/20BBF	26.3 ±0.3	24.2 ±0.4	4.6 ±0.1	4.6 ±0.4

*after accelerated weathering (AW)

The fact that the ultimate tensile strength of composites after accelerated weathering, reduced according to the fiber volume, as observed on the values of Tab 2, indicated that lignocellulosic fibers added to the polymer matrix, suffered degradation processes.

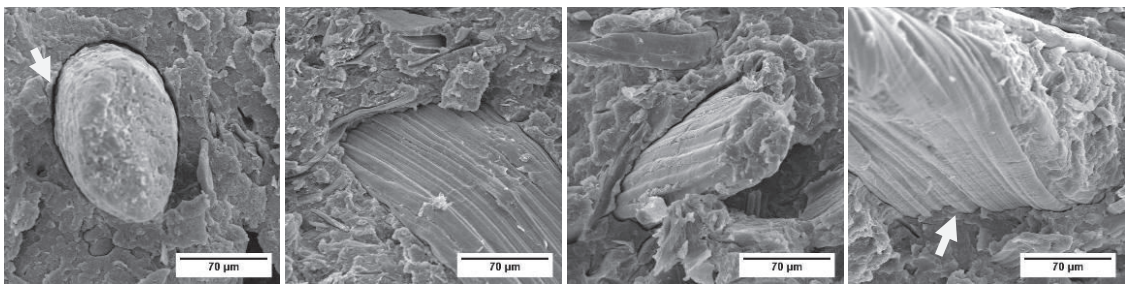
The values of tensile modulus increased with fiber volume regarding the pure HIPS. It was also observed a modulus increases of exposed composite in respect to the unexposed, showing that degradation of these fibers has influenced in the fiber mechanical properties, and as a consequence the

mechanical properties of the composite, so it is evident that the fiber/matrix interaction was not affected.

Thus it was evident that exposure of the material to moisture and UV-B radiation affected more lignocellulosic fibers than fiber and matrix interfacial region.

Analyzing the different chemical treatments applied to fibers surface, it was observed that bleached fibers, due to the higher amount of lignin removed with treatment, it has a higher mechanical interaction with the matrix, observed in composites fracture surface indicated in Fig 2.

Cellulose, the main component of lignocellulosic fibers, due to its crystalline structure is completely insoluble in water, whereas lignin, which is partially removed with chemical treatments, with amorphous structure is more susceptible to water absorption and UV radiation. Thus, as mercerized fibers have a higher amount of lignin than bleached fibers, keep more susceptible to UV radiation and moisture [11].



(a) (b) (c) (d)

Fig. 2. SEM of composites fracture surface before the exposure: (a) HIPS/20MBF, (b) HIPS/20BBF and after exposure (c) HIPS/20MBF, (d) HIPS/20BBF.

4. Conclusions

Degradation process, caused due to exposition to accelerated weathering, was been influenced by fiber volume and chemical treatment.

The influence of weathering exposition is more effective in the composites when compared to the pure HIPS, indicating that fibers decrease the degradation resistance of material, although the exposure did not cause the degradation process of fiber/matrix interface, confirmed by the SEM analysis.

About chemical treatments it was verified that, as bleaching treatment removed residual lignin, composites reinforced with these fibers are less susceptible to UV radiation and moisture.

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